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ABSTRACT

The document is a student resource unit to be used in teaching high school vocational agriculture students about water. The hydrologic cycle and natural processes are described, with particular attention to evaporation, precipitation, and runoff. Sources of water pollution are found in industries, municipalities, individual action, and agriculture. Damage to health, recreation, esthetics, fishing, agriculture, and water supplies are some of the results of water pollution. The present situation is assessed in terms of potential controls, nutrient enrichment, toxicity levels, waste heat, governmental programs, monitoring, and the special problems of agriculture. The document concludes with eighteen recommendations to improve water quality. A twelve-item bibliography is included. (MS)

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Ag Ed Environmental Education Series

WATER

WASHINGTON STATE UNIVERSITY IN COOPERATION WITH THE COORDINATING COUNCIL FOR OCCUPATIONAL EDUCATION.

73-3H

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Environmental Education Series

- Air
- Agricultural Chemicals and Radiation
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- Land Use
- Noise
- Plants
- Understanding the Environment
- Water

ED 084425

WATER

by

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FOREWORD

This publication is the product of a project carried on by the Coordinating Council for Occupational Education and the Department of Education, Washington State University.

The project grew out of a recognition of the need to include as a part of the high school vocational agricultural education curriculum information dealing with the environment, particularly as it relates to agriculture. The project was preceded by a period of growing concern that a body of factual information and teacher resources needed to be developed in this area.

E. M. Webb, associate professor of agricultural education emeritus, first suggested that steps be taken to make available to teachers of agriculture and their students factual information on the environment and agriculture. It was through the efforts of Jay Wood, program director, agricultural education, Olympia, that a project was prepared and approved beginning in September 1970.

Valuable assistance was given the project by many persons from the following agencies: Washington State University, University of Washington, Western Washington State College, Soil Conservation Service, United States Department of Agriculture, United States Department of the Interior, Washington Parks and Recreation Department, Washington Department of Ecology, Washington Department of Natural Resources, Washington Department of Agriculture, Washington Department of Fisheries, Washington Water Pollution Control Commission, Environmental Protection Agency, and Washington Department of Game. Many other agencies provided information for the project.

Three publications were extremely useful in preparing this unit. They were *Environmental Quality: The First Annual Report of the Council on Environmental Quality*, *Environmental Quality: The Second Annual Report of the Council on Environmental Quality*, and *Wastes in Relation to Agriculture and Forestry*. Information from these publications was used as a basis for much of this unit.

Grateful acknowledgment is hereby made to the following groups of people: Dr. C. O. Loreen and Dr. Keith E. Fiscus, both teacher-educators and State supervisors in agricultural education, and Mr. Jay M. Wood, program director, agricultural education, who gave able assistance to this endeavor. Mr. Pat Alleyn, Mr. Wallace Caldwell, Mr. Charles Clark, Mr. Ronald Everts, Mr. Eugene Forrester, Mr. George Frederick, Mr. Gary Ogden, and Mr. Keith Sarkisian, teachers of agricultural education in Washington high schools, reviewed the unit, developed teaching materials to be used with the unit, and taught the unit to their students. Many other teachers also made valuable contributions to the project.

The following subject-matter specialists reviewed the unit: Mr. Bobby Carlile, junior soil scientist, Washington State University; Dr. C. B. Harston, extension soil and water conservationist, Washington State University; and Mr. Roger James, supervising public health engineer, Department of Social and Health Services, State of Washington.

This unit is one of eight being produced under the project. The other seven include: *Understanding the Environment, Land Use, Noise, Agricultural Chemicals and Radiation, Animals, Plants,* and *Air.*

July 1972

Rodney W. Tulloch

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INTRODUCTION

President Richard M. Nixon's message to the Congress in August 1970, included the following statement:

> The basic causes of our environmental troubles are complex and deeply embedded. They include: our past tendency to emphasize quantitative growth at the expense of qualitative growth; the failure of our economy to provide full accounting for the social costs of environmental pollution; the failure to take environmental factors into account as a normal and necessary part of our planning and decisionmaking; the inadequacy of our institutions for dealing with problems that cut across traditional political boundaries; our dependence on conveniences, without regard for their impact on the environment; and, more fundamentally, a failure to perceive the environment as a totality and to understand and to recognize the fundamental interdependence of all its parts, including man himself.

It should be remembered while studying this unit on water that this is only one small part of ecology. Ecology is the study of interrelationships between living organisms and their surroundings.

This unit covers mostly present-day problems of an environmental nature concerning water. It should be remembered that water has had an important place in man's history. Many of the great societies of early times developed where there was water available. Even in the United States many of the great cities were located so as to take advantage of a source of water.

Water has also been the source of many problems of man. Some of these problems include drought, floods, and epidemics caused by disease-carrying water. During the mid-19th century, there were great typhoid epidemics in London. The concern for these widespread epidemics dominated the scene in regard to water pollution until recent times. Since preventing waterborne disease was the major concern of pollution abatement efforts, most of this activity has been controlled by State health departments. This chain of events has left its mark on the types of water pollution control activities that have been carried out.

Only recently has broader legislation to more comprehensively control water pollution been enacted. Rapid changes in attitudes toward water pollution have been due to several causes. These include the fact that epidemics due to waterborne causes have been virtually eliminated, the growth and concentration of industries and cities have greatly increased pollution in many waterways, a society with greater affluence and leisure has demanded more outdoor recreation, and, finally, man has a continuing desire to be near and enjoy water.

Although water pollution exists in all parts of the United States, it tends to be much worse where high population and industrialization combine. Therefore, water pollution problems are particularly severe in the Northeast and Great Lakes regions. In these areas as well as many others, industrialization and urbanization have combined with a lack of sewage treatment facilities to pour large accumulations of pollution into rivers and lakes.

Many are saying that the early 1970s may be a time that historians will point to as a turning point in attitude toward the environment. Although the environment may not be significantly changed for the better, people have become aware of water problems. This awareness may become the turning point toward cleaner water. Yet, we who live in the early 1970s will have to be the first to admit that we have only begun to tackle the problems.

One of the most widely used chemical tests of waters containing organic wastes is for *biochemical oxygen demand (BOD).* BOD indicates the amount of oxygen required for oxidation (consuming or breaking down) of the organic matter present in a sample of water. BOD is expressed in *parts per million (ppm)* of oxygen absorbed by organisms in a waste water sample that has been incubated for a 5-day period at 20°C (68°F). When water in the 5-day test absorbs 5 parts per million or more of oxygen, it is considered to be of doubtful purity. (One teaspoon of water added to five barrels is about one part per million.)

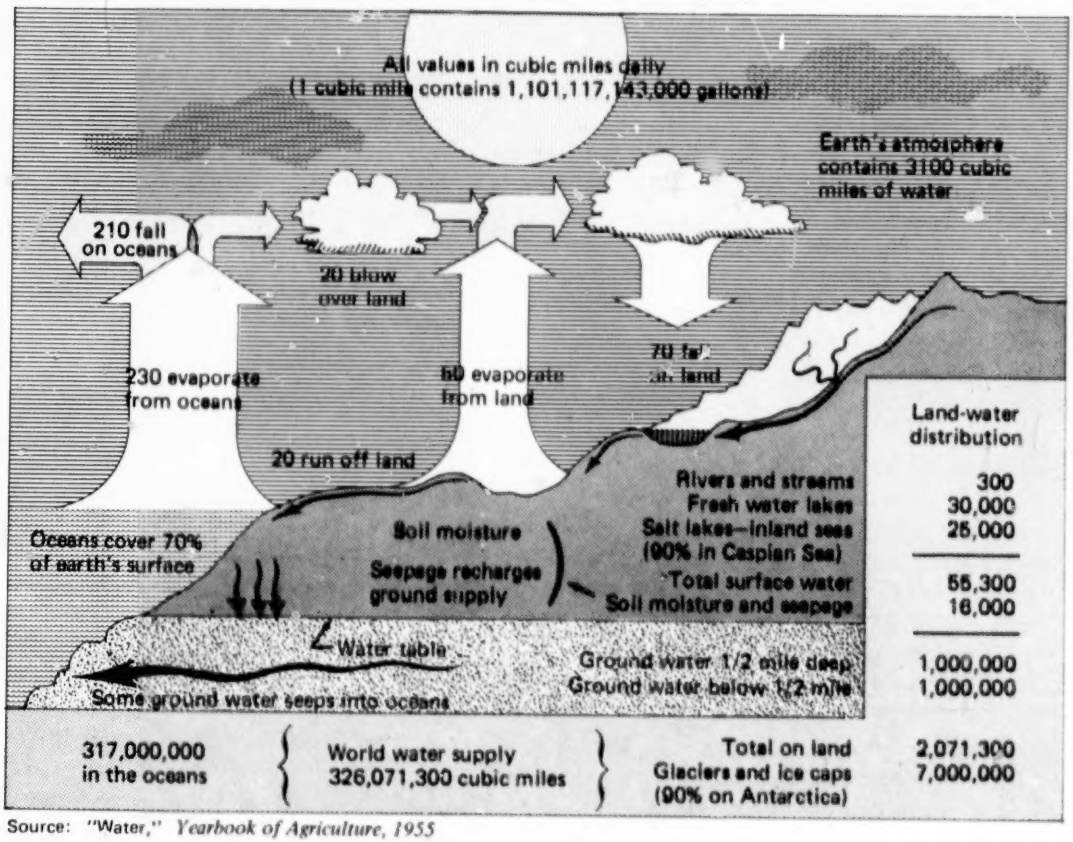
The Environmental Protection Agency (EPA) is trying to eliminate BOD as a major test because of its variability. They prefer using total organic carbon (TOC) instead. When the BOD reaches a level at which there is no oxygen left in a stream, it becomes impossible for aerobic bacterial action to continue. Three factors combine to cause very serious problems as temperatures rise. First, in bodies of water that feed streams, the heat accelerates the biological and chemical processes that reduce the ability of the water to retain dissolved oxygen and other dissolved gases. Second, as temperatures rise, the oxygen becomes less soluble. Third, this water with little or no oxygen is then dumped into the stream, which is usually at its lowest flow. The combination of these three factors may change the bacterial action from aerobic to anaerobic very rapidly. The water then takes on many undesirable characteristics such as darkening in color and undesirable odors.

Sediment consists of solid particles such as soils, sands, and minerals. Depending on the size of the particles and speed of flow, sediment may be suspended in the water or bounced along the bed of the stream. As the speed of flow decreases, smaller and smaller particles become deposited. The process of sedimentation takes place in three stages: erosion, transportation, and deposition of sediments.

Two major types of bacterial action are discussed in this unit. First, is *aerobic bacterial action*, which requires the presence of oxygen. As long as oxygen is present in water and aerobic action takes place, organic wastes are broken down with a minimal amount of problem. Some of the bacteria that thrive in the presence of oxygen may survive or even continue to function without oxygen. *Anaerobic bacteria*, which may function or fail to survive in the presence of free oxygen, are much less common. Anaerobic bacteria prefer to function in an environment that lacks free oxygen. The process of fermentation is often referred to as anaerobic. However, true anaerobic action differs from fermentation. A true example of anaerobic action may be seen in the bubbling methane (marsh gas) in swamps and ponds where the anaerobic bacteria are decomposing organic matter. Anaerobic action in a stream or pond may damage esthetics through undesirable odors and severely darken the color of the water.

HYDROLOGIC CYCLE AND NATURAL PROCESSES

Some of the earth's water is bound up in sedimentary rock; some follows a continuous sequence of evaporation, precipitation, runoff, and storage. This unending circulation of the earth's moisture and water is called the hydrologic or water cycle (fig. 1). This enormous system operates in and on the land, the oceans, and the atmosphere of the earth. Since the hydrologic cycle or water cycle is unending, we will arbitrarily take evaporation as a point in the cycle at which to begin the discussion.


All values in cubic miles daily
(1 cubic mile contains 1,101,117,143,000 gallons)
Earth's atmosphere contains 3100 cubic miles of water
210 fall on oceans
80 blow over land
70 fall on land
230 evaporate from oceans
80 evaporate from land
20 run off land
Land-water distribution
Rivers and streams 300
Fresh water lakes 30,000
Salt lakes—inland seas (90% in Caspian Sea) 25,000
Total surface water 55,300
Soil moisture and seepage 16,000
Oceans cover 70% of earth's surface
Soil moisture
Seepage recharges ground supply
Water table
Ground water 1/2 mile deep 1,000,000
Ground water below 1/2 mile 1,000,000
Some ground water seeps into oceans
317,000,000 in the oceans
World water supply 326,071,300 cubic miles
Total on land 2,071,300
Glaciers and ice caps (90% on Antarctica) 7,000,000

Source: "Water," *Yearbook of Agriculture, 1955*

Figure 1.—Hydrologic cycle.

Evaporation

The amount of water returned to the atmosphere by evaporation is a little more than two-thirds of the total precipitation on the land. Evaporation comes from many sources including falling rain, soil, ponds, lakes, plants, rivers, reservoirs, and the oceans. The oceans contribute the largest part to evaporation—approximately 80,000 cubic miles of water per year. Lake and land surfaces of the continent contribute about 15,000 cubic miles to evaporation per year. Many factors affect the rate of evaporation. Some of these include temperature, type and condition of land or water surface, plant growth, and the moisture already in the atmosphere. Moisture from the earth's surface is drawn into the atmosphere, forming moisture-laden clouds.

Precipitation

There are three major conditions or storms that operate to bring precipitation back to earth. The first is the orographic or mountain type of storm, which is caused when warm air has to rise over a mountain range. A good example of this in the State of Washington is the Cascade Range. Warm air rising over the mountains condenses into droplets that gradually get larger until the air is no longer able to hold them up, and precipitation takes place. Orographic precipitation is generally of low intensity. However, because of the fixed location of the mountains and the general eastward movement of the moist air from the Pacific, these areas tend to have a high total rainfall.

A second type of condition or storm is the cyclonic or low-pressure-area type, which produces general rain over wide areas. It is particularly prevalent during winter. Cyclonic storms are then produced by cold polar air masses interacting with the warm tropical air masses. In this interaction, the warm moist air is lifted over the heavier cold air and at the same time cooled to form precipitation.

The third major type of condition or storm is the convectional or thunderstorm type, which is caused when a relatively small area is heated to a greater extent than the surrounding area. This may take place around a city, a lake, or a large open field. As any of these areas are heated more rapidly than the surrounding area, the warm air above them begins to rise. As this air rises, cooling and condensation take place, and if this is carried on long enough, precipitation forms.

Two or three of these major types of conditions may work together to form even different patterns of precipitation.

With this brief discussion, it is fairly easy to see why precipitation varies from over 100 inches in areas of the Pacific Northwest to less than 5 inches over certain desert areas. What happens to this precipitation? If we take an annual rainfall of 30 inches, approximately 21-1/2 inches is evaporated into the atmosphere from the soil, plants, or surfaces of lakes and streams. About 3 inches seeps down through the soil from rock layers into the ground layer. Approximately 5-1/2 inches runs off directly into streams or moves through the uppermost horizons of the soil to enter the nearest stream.

Runoff

Although evaporation and precipitation are important to agriculture, runoff is probably the most important problem. As precipitation falls to the earth, it is often interrupted in its fall by vegetation. Leaves, branches, and organic matter serve as barriers to precipitation. Thus, only part of the precipitation reaches the soil. Vegetation then affects the quantity and distribution of precipitation that reaches the soil. Although the quantity of precipitation evaporated from vegetation varies, depending on the kind and duration of storms and the kind of vegetation, it usually amounts to 5% to 15% of the annual rainfall. Precipitation reaching the soil may infiltrate into the soil. The amount of infiltration that takes place will depend on the form of the precipitation, the rate of precipitation, and the infiltration rate or receptiveness of the soil. When the precipitation rate reaches the infiltration rate, the excess becomes runoff.

Runoff is undesirable because it allows water that may be needed later to escape. Runoff may also cause severe erosion problems. Two types of erosion problems are of a serious nature: First, the erosion may remove valuable soil, plant nutrients, minerals, and other material from areas where they are needed. Second, erosion may cause siltation and sedimentation problems in the rivers and streams into which the runoff water flows (fig. 2).

USDA Photo

Fig. 2.—Just one rain washed enough soil from the sloping field to fill this roadside ditch.

The amount of runoff may be controlled to some degree by the type of vegetation grown and cultural and mechanical practices used on the land. Water that infiltrates the soil either increases its moisture content or drains through it. The amount of moisture that a soil layer or horizon will hold is referred to as field capacity. As each horizon is raised to field capacity, moisture continues to drain through it to deeper layers. When the entire soil profile has reached field capacity, any additional water entering the soil drains into the parent material and is then called ground water.

SOURCES OF WATER POLLUTION

Before we begin a discussion of sources of water pollution, it is important that we realize that very little if any pure water exists in nature. By pure water we mean 100% H_2O with no impurities. Water in nature, including crystal-clear mountain streams, contains small amounts of dissolved materials from soil and rocks. Even rain water contains soluble gasses and suspended dust that it picks up in its fall through the atmosphere. Water is an excellent solvent or suspending agent for many things. Therefore, it becomes polluted readily. Since almost all water has impurities in nature, the point at which we begin to refer to it as polluted is when it contains more foreign matter than can be tolerated for the purpose for which we intend to use the water. The principle sources of water pollution are domestic wastes (sanitary sewers), industrial wastes, and agricultural runoff.

Industries

Many of the more than 300,000 factories that require water in the United States had the availability of water as a major consideration in establishing their location. Historically, industries have used water for many purposes, including the production of power. Even today with all of our technology many industries are tied to water as their lifeline. At present, United States industry discharges three to four times as much oxygen-demanding waste as all the sewered population of the United States. Even more tragic is the fact that much of the waste discharged by industry is toxic. Industrial wastes are increasing at a rate several times faster than the ability to treat those wastes. The first annual report of the Council on Environmental Quality says that "Although there is as yet no detailed inventory of industrial wastes, indications are that over half the volume discharged to water comes from four major industry groups—paper, organic chemicals, petroleum, and steel."

The greatest quantities of industrial waste tend to be discharged in the areas of greatest population. It is, therefore, not surprising that the greatest volumes of discharge of industrial waste are in the Northeast, the Ohio River Basin, the Great Lakes, and the Gulf Coast States. Other areas also have problems (see fig. 3). This is not to say that the State of Washington does not have problems. As the rivers, streams, and lakes of the East become more and more polluted, it is only natural that men and industries move West to take advantage of the clear streams in this section of the country.

Although abundant quantities and good quality of water are required by many industries, many of the same industries are using much larger quantities of water than is actually required for their manufacturing processes. This has often been true because industry has operated under economic incentives that have caused low-priced materials to be used in great quantity. Correctly caring for our waters is not cheap, and industry leaders are beginning to realize this. Realization by industrial leaders that the treatment of large volumes of water is expensive should in itself help prevent further pollution of our rivers, lakes, and streams.

Most industrial water pollution can be curbed, and much has already been done. Technology can and has designed production processes and treatment facilities that will minimize the amount of waste water returned to our rivers and streams. An example is that the average waste from a modern sulphate pulp and paper plant is only 7% of what it was a few years ago. The total estimated cost to all industry is less than 1% of gross sales. In some industries, however, the figure is much higher. New plants being constructed in some areas of the Northwest are costing companies 5% to 7% more to build in order to obtain the kind of facility that will enable them to minimize pollution.

Although technology has done much, some industrial pollution presents nearly impossible abatement problems. This is particularly true of very toxic materials that are produced as end products or as byproducts. The product (or byproduct) may accidentally be spilled or otherwise allowed to enter water. Many of these chemicals are very difficult to detect and to control.

Oil and other hazardous substances are being recognized as major problems. Oil spills have hit the headlines and dominated the news thus making the population aware of this serious problem. It is estimated that there are 10,000 spills of oil and other hazardous materials annually in navigable waters in the United States. Spills of other hazardous substances besides oil can be at least as important and maybe more toxic than oil spills. The volume of oil makes it the most important single pollutant of this type. Most major oil spills that exceed 100 barrels come from vessels. About a third of the oil spills involve pipelines, oil terminals, and bulk storage facilities. Damage to vessels is a prime source of oil pollution and can spread millions of gallons of oil at one time and place.

USDA/SCS Photo by E. F. Saver

Fig. 3.—The pumping of raw waste into this river has caused a health hazard, and all fish have been killed.

There are also many other sources of hazardous substance spills. One of these is the disposal of 350 million gallons of used oil per year by gasoline service stations. Blowouts of offshore oil and gas wells is another source of oil pollution. Leaks in pipelines may also allow hazardous substances to enter waterways. The dumping of drilling muds and oil wastes and accidents of offshore drilling rigs may all constitute hazards in the form of water pollution.

As the amount of oil and hazardous materials being transported increases, the number of spills could increase. New and better regulations and sounder planning and development by industry could, however, reduce the number of spills.

Mine drainage is another important source of water pollution, particularly in Appalachia and in the Ohio Basin States. Acid drainage from the mines is the greatest problem contributing to lowering the quality of streams, lakes, and reservoirs in the area. Acid drainage may come from coal, phosphate, sand and gravel, clay, iron, gold, copper, and aluminum mines. Although acid is the major pollutant from mine drainage, it may also include copper, lead, zinc, and other metals toxic to aquatic life. When water and air react with sulfur-bearing minerals in mines or in refuse piles, they form sulfuric acid and iron compounds. Acid discharges may still be of serious consequence after some mines have been left idle for 30 to 50 years.

Another pollution problem is wastes from water vessels. The total pollution from vessels when compared with total sources of pollution is relatively insignificant. However, the pollution from vessels can be of a very serious nature in a harbor or recreational area. There are approximately 111,000 commercial vessels using United States waters. There are also about 1600 Federally owned vessels and eight million recreational watercraft using United States waters. The potential sewage from these vessels is estimated to equal that of over 500,000 persons. This would compare to the population of a city the size of San Diego.

A lack of research and study has preceded the processing and marketing of some materials. This lack of caution has caused growing anxiety among some scientists and citizen groups. New devices and techniques for measuring chemicals have been developed and are helping scientists detect very minute quantities of many kinds of chemicals. It may be that these new techniques and methods are what have helped scientists find small quantities of material that until now have not been detectable. For example, certain heavy metals can be a problem but have had very little attention paid to them until recently. Certain fish have been found to contain fairly high levels of mercury and have been banned for human consumption by the Food and Drug Administration. Since measurements for many of these materials have not been available until recently, there is some question about the levels that existed many years ago. A study of a very old fish at the Smithsonian Institution in Washington, D.C., revealed that this fish had high levels of mercury in its system. This fish lived long before any of the industries with which we are now familiar were doing any polluting.

In the future, one of the most serious water pollution threats may be that of heat. Pollution from heat is called thermal pollution. The largest source of thermal pollution today is the electric power industry. The electric power industry uses tremendous amounts of water for cooling and for hydroelectric power. It is the cooling process that contributes so greatly to thermal pollution. Many other industries also use water as a coolant, thus thermally polluting water. These include the petroleum, chemical, steel, and pulp and paper processing industries.

Future thermal pollution problems may best be indicated by a look at the increases in generation of electricity being forecast. Presently, the electric power industry is growing at a rate of 7.2% annually. This means that the electrical power industry is nearly doubling every 10 years. Many experts predict that this trend will continue for the foreseeable future. It has been estimated that, by 1980, the increasing demand of the electric power industry will require the equivalent of one-fifth of the total fresh water runoff of the United States.

All, however, is not gloomy. Many large industries have their top executives as well as large amounts of manpower working on the problem. New processes and technology are being developed, and it seems certain that the pressure from citizens will continue to require their rapid adaptation.

Municipalities

Less than a third of the nations's population is served by sewers and adequate treatment facilities. Another third is served by sewers that are not connected to adequate treatment facilities. About 5% of these discharge waste with no treatment. The remaining third of the population is served by no facilities at all. In the United States, approximately 45% of the waste processed by municipal treatment facilities is from industries. The other 55% of wastes treated by municipalities is from domestic sources (homes, apartments, and commercial establishments, see fig. 4). As with industries, the greatest municipal waste problems exist in the areas of heaviest concentrations of population, particularly the Northeast. It has been estimated that approximately 60% of the population served by sewers has inadequate treatment facilities.

Fig. 4.—Sources of municipal waste.

Many municipalities actually have two sewer systems. The two systems are the sanitary sewer system and the storm sewer system. The sanitary sewer system is the one that carries the domestic, commercial, and industrial wastes. Some specific wastes carried by the sanitary sewer system are water used for toilets, bathtubs, sinks, washings from restaurants, laundries, hospitals, hotels, industrial wastes, and many others. Storm sewers are the sewers that carry surface runoff to a river or other storage place. Much of the runoff water is relatively clear as it falls in the form of precipitation. However, it may become seriously polluted as it runs through the streets, alleys, and other areas before it enters the storm sewer system. Municipalities that have only one joint sewer system may have severe problems during rain storms. The large volumes of water from the storm may overload the treatment facilities so that raw sewage is allowed to leave the treatment plant.

Each day approximately 60,000 acre-feet of water flow from municipal sewage facilities in the United States. This would amount to 1 foot of water over 60,000 acres. Some of this large volume of sewage may be usable for irrigation purposes. Obviously, sewage that has received a minimum of treatment cannot be used for irrigation of food crops. Water that can't be used for irrigating food crops may be usable on feed and fiber crops. Filtering through the soil has proven to be one of the best methods of purifying water. The State agricultural experiment stations and many agencies of the United States Department of Agriculture have done research using sewage for irrigation purposes.

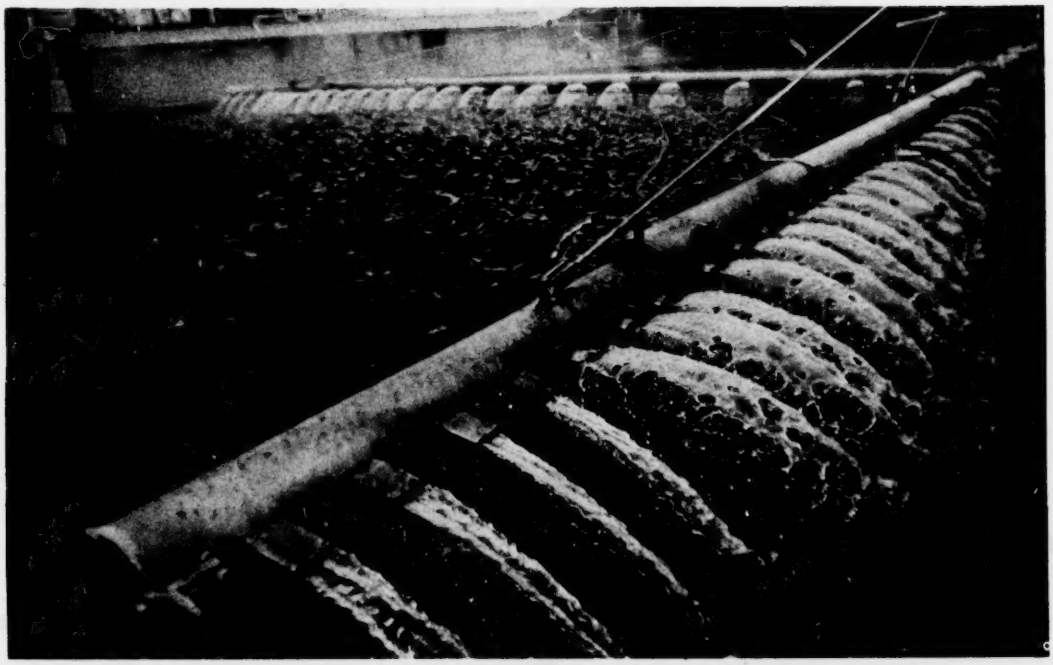
Municipal treatment plants can be classified as one of three levels. The three levels are primary, secondary, and tertiary. Primary treatment is a simple gravity process that separates and settles solids. This process can be observed by mixing soil particles and water in a glass container. As time passes, the soil particles will settle to the bottom.

Primary treatment provides removal levels of 25%-30% of measured BOD. It is important to note that this does not mean that 25%-30% of the total oxygen-demanding wastes are removed. We are talking here only of the part that is measured by specific laboratory tests. BOD is, however, a figure that is often given to indicate the oxygen demands of waste. COD or chemical oxygen demand is a more inclusive measure of the amount of oxygen required to decompose wastes.

Secondary treatment is a biological process. Essentially secondary treatment does in natural water bodies what nature would do, only it does it more rapidly. Many large cities use an activated sludge process. In this process, air and bacteria are mixed with sewage to accelerate the decomposition of wastes. The other secondary treatment process is the trickling filter process. This process involves spraying wastes mechanically over an area usually consisting of a rock bed (fig. 5). The presence of air helps to form bacteria on the rocks which in turn helps to accelerate the decomposition of wastes. Approximately 90% of the measured BOD can be removed by good secondary treatment.

Tertiary treatment, sometimes called advanced waste treatment, uses a variety of processes that can be tailored to meet specific needs. Measured BOD levels can be lowered up to 99% using carbon absorption and sand filtering. About 80% of phosphate can be removed from waste water with the use of the lime-alum precipitation process. This certainly compares favorably with the average of 30% phosphate removal in normal secondary treatment.

Even if technological advancements can substantially lower industrial and municipal waste loads, there are still problems to be faced. Large population areas with their highly industrialized complexes will continue to exceed their capacities to assimilate wastes. Present estimates are that municipal systems will have to expand to handle waste loads of nearly four times what they are now processing in the next 50 years.



CCOE Photo by Alex Crewdson

Fig. 5.—Slowly revolving pipes spray waste water over beds of stones where bacteria consume organic matter.

A major portion of the usable phosphates contributed to water bodies comes from municipal wastes. High nutrient levels in waste discharges have already led to severe problems in the Great Lakes and several other areas. Secondary treatment plants average 30% removal of phosphorous. With modification, higher levels of removal are possible. Even this improvement is probably not enough in highly populated industrialized areas. If the phosphate contents of detergents and other such problems are not overcome, many high-population areas may require treatment levels approaching 100% removal of nutrients.

Individuals

Although the major sources of water pollution are industrial, municipal, and agricultural, individuals are also very important. Individuals are contributing substantially to municipal wastes. When individuals are not contributing to municipal wastes, they usually are contributing directly to streams or into septic tanks from which pollution may enter ground water. Our society is demanding an increase in outdoor recreation facilities. Persons using outdoor recreation facilities have not completely learned proper use of such facilities. This has made difficult problems for park and recreation people who have spent time cleaning up behind inconsiderate users instead of planning and developing new facilities. Many agencies are spending numerous man-hours in trying to train outdoor recreation enthusiasts to better use facilities. Some of the work done by these groups should seemingly be unnecessary in an intelligent society (for example, potty-training campers at State and national parks). Even with the programs being carried out, many parks and recreational facilities continue to be abused and to contribute to water pollution because of these abuses.

Man's attraction to and appreciation of water dates back to early history. However, as our lakes and streams become more polluted, enjoyment and appreciation of them becomes more impossible.

Individuals use many materials, such as chemicals, which also add to the pollution of our lakes and streams. An increased awareness of these problems will encourage individuals to do less damage to the environment.

Agriculture

Sediment

Sediment has been listed as a subheading under agriculture. It is, however, important to note that there are many other sources of sediment. Erosion-caused sediments represent the greatest volume of wastes entering surface waters. The volume of sediments reaching U.S. waters is more than 700 times that of total sewage discharge loadings (fig. 6). Sediments are carried off in runoff from cropland, unprotected forest soil, overgrazed pastures, strip mines, roads, and unprotected urban areas. Total sediment production in the United States amounts to approximately 4 billion tons a year. In a sampling across the Nation, amounts of sediment found varied widely from 51 to 10,000 tons per square mile. This great variation in amount of sediment is based on many factors, including soils, geology, topography, precipitation, vegetative cover, and conservation practices. That each of these factors has important effects upon sediment has been proved time and again across the country. Many experiments run at experiment stations have proven that sediment can be reduced by use of good conservation practices.

In 1969, the Federal Water Quality Administration, which has now become part of the Environmental Protection Agency (EPA), issued a report. In this report it was estimated that the average sediment yield during a rainstorm at highway construction sites is about 10 times that for cultivated land, 200 times that for grass areas, and 2000 times that for forest areas. The exact amount would depend on the amount of rainfall, the slope of the land, and the exposure of the bank. Similar amounts of sediment may be produced on commercial and industrial construction sites.

Plant Nutrients

Sediments contain various amounts of plant nutrients. Thus, controlling sediment will also help control plant nutrients entering surface waters. Meeting ever-increasing food demands has required higher crop production, which in turn has required the application of greater amounts of plant nutrients. In 1966, Americans applied 32 million tons of chemical fertilizers. These fertilizers were applied to lawns, gardens, orchards, fields, forests, and pastures. This seemingly large tonnage of commercial fertilizers is often blamed for the adverse effects of plant nutrients in surface water. Actually, the largest source of plant nutrients is municipal sewage.

The United States has not been economically pushed to use plant nutrients in the high volumes used in some other countries. For example, in the Netherlands in 1965 there were 11 times as many pounds of nitrogen per acre applied as in the United States. In that same year, there was 5.8 times as much phosphate applied. When we use the term phosphate here, usually written P_2O_5, we are referring to phosphoric acid equivalent. It should be noted that there is no P_2O_5 in phosphorous fertilizer and only small amounts of phosphoric acid.

Fig. 6.—Silt from denuded watersheds have choked reservoirs, led to floods, and wasted water.

It is the phosphoric acid equivalent that is guaranteed in the analysis of the fertilizer. Also in 1965, the Netherlands applied 8.9 times as much potash (K_2O) as did the United States per acre.

Two major concerns arising from plant nutrients in water are nitrate in drinking water and eutrophication of lakes and streams.

It has been known for a long time that nitrate moves into ground water. It may also be carried into surface water. In the early 1900s in Colorado, H.P. Headden found high quantities of nitrate in ground water before chemical fertilizers had been used in the area. He reasoned that the nitrates had been leached to these deep horizons after being formed naturally in the surface soil. In Franklin County, Washington, district health officer Vernon Michael suggested that heavy use of nitrogen fertilizer had resulted in heavy concentrations

of nitrates in drinking water. Many other examples could be given of high nitrate levels in wells and other water in areas where high applications of fertilizers have been applied.

At Washington State University, the Soils Department has studied the nitrate content of well water. It has been shown that high nitrate concentrations in well water are not a direct consequence of heavy fertilizer use. Likewise, G. E. Smith has reported on extensive studies of nitrate content of 6000 rural Missouri water supplies. His evidence shows that leaching of fertilizer nitrogen is an insignificant source of nitrate. He also found that animal wastes, improperly constructed shallow wells, and septic tank drainage were main contributors to water contamination. Obviously there is some conflicting evidence. Conclusive evidence of far-ranging detrimental effects of the application of chemical fertilizers is not presently available.

Nitrification processes are causing serious problems and even occasional deaths in infants, so research will need to be continued on this important problem to gain vitally needed information.

Eutrophication, the second major concern caused by plant nutrients in water, is the process of "dying" of lakes. The process of eutrophication is natural. However, man is beginning to speed this process up many times faster than normal. An example of a lake in early stages of this process at present is Lake Superior, which is deep and has little biological life. Lake Ontario is an example of a second stage in which the addition of nutrients and sediments have made the lake more biologically productive and shallower. In the third stage, more nutrients are added, large algal blooms grow, and species of fish change as the lake develops undesirable characteristics. An example of a lake in this stage is Lake Erie. When the algal blooms die and deteriorate, they cause unpleasant odors. If the decaying plant life takes too much dissolved oxygen from the stream, the water becomes uninhabitable for fish. Like other plants, algae require mineral nutrients to grow. The limiting factor for algae growth in most waters is lack of phosphorous. Thus, phosphorous takes on a role of great significance.

Clay soil particles hold several times the amount of phosphorous adsorbed by soil made up of sand particles. Therefore, the higher the percentage of clay particles a soil contains, the greater its ability to adsorb phosphorous. Consequently, since the phosphorous is connected to the soil particles, more phosphorous may be washed into streams by soil erosion.

Soil particles hold tightly onto phosphate molecules. Even when fine soil particles that have thousands of parts per million of phosphorous on their surfaces are suspended in a river, only 0.005 to 0.0005 part of phosphorous per million may truly become phosphorous in solution. Therefore, water samples should be analyzed in a way that will measure the amount of phosphorous in true solution. However, when aquatic plants are growing in sediment, the problem becomes much more difficult. Their roots may remove some of the phosphorous adsorbed on soil particles.

The problem of speeded up eutrophication will require considerable research. The main concern with phosphates on sediments is in lake systems where sediments are deposited in anaerobic zones that cause some of the phosphates to become soluble and the sediments, by diffusion, serve as a continuous supply of available phosphorous to the overlaying waters. The importance of phosphorous can be seen even more readily when examined in light of present evidence, which indicates that algae will grow vigorously if the water contains 0.1 part per million of phosphorous. To completely inhibit the growth of algae, phosphorous levels must be below 0.02 part per million. Each year in the United States approximately 1 million tons of elemental phosphorous is applied as fertilizers. If 10% of the phosphorous applied is assumed to reach streams as soluble phosphate, the average phosphorous of our

streams would be 0.05 part per million. Using these figures as a basis, it is easy to erroneously conclude that phosphorous in surface waters is coming from fertilizer application.

Presently, an average of 2 pounds of phosphorous per person per year is delivered in metropolitan sewage effluent. This is due largely to the use of household detergents. The public health service reports, however, that Lake Washington near Seattle receives 3.4 pounds of phosphorous per person per year from the treated sewage of over 76,000 people. In a hypothetical situation, then, a city of one million people could produce 1000 tons of phosphorous a year in its effluent. If this amount of phosphorous were then put into a stream with an average annual flow of 10,000 cubic feet per second, the average phosphorous content of the water would be 0.1 part per million. This is, of course, an adequate level for the growth of algae. (An example of a river with an average annual flow of nearly 10,000 cubic feet per second is the Potomac.)

Reports have been made which imply that phosphorous in surface waters is quite directly the result of fertilizer applications. J. Derduin's presentation at the American Association for the Advancement of Science Symposium, December 27, 1966, found agricultural fertilizers to be only a secondary source of phosphorous enrichment of surface waters. His careful examination of the evidence found that most phosphorous enrichment of surface waters is coming from sewage treatment plants.

Erosion products reaching farm ponds have generally been insufficient to provide growth of aquatic life for fish food. Therefore, the management of ponds has required the addition of plant nutrients. This permits the growth of an adequate supply of microscopic plants for fish food. This extensive use of fertilizer in farm ponds for fish production certainly would indicate that land runoff into the ponds is a poor source of needed phosphorous.

Phosphorous that is getting into streams from farmland comes mainly from surface water through runoff and erosion of topsoil. However, water that seeps through the soil or moves laterally through the soil carries very little phosphorous because of the high capacity of soil particles to attract phosphate. On the average, topsoil contains about 200 parts per million of phosphorous adsorbed on soil particles.

Inorganic Salts and Minerals

Approximately half of the fresh water that we use annually is used for irrigation. This, of course, makes agriculture the largest user of fresh water. Large amounts of water used for irrigation are evaporated. As this evaporation takes place, inorganic salts and minerals are left behind. The amount of inorganic salts and minerals thus becomes more concentrated in the drainage effluent from irrigated areas.

The value of irrigation has long been known to man. Early civilizations in the valley of the Nile used irrigation. Plants also tend to take up water, leaving the salt behind to become more concentrated. The amount of salt concentration that can be allowed to accumulate in the soil must be limited for the soil to continue to be productive. Thus, leaching of these salts must take place if the soil in irrigated areas is to continue to be used for agricultural purposes. Leaching is a process in which water passing through soil carries with it soluble materials. In order to leach a soil, excess water, as compared to the amount needed for irrigation, must be applied.

The farmer using irrigation produces very little if any dissolved salts in waste form. What he does do is transfer the waste in a more concentrated form. However, this may in some cases be enough to label the quality of water as being impaired because of its burden of dissolved salts. This problem may become even more intensified in areas where water for irrigation is limited. In these areas, the water may be reused several times, increasing the salt concentration each time that it is used.

The amount of salt tolerance for different kinds of uses varies widely. Very low tolerances have been set by the Public Health Service for human consumption. We may be able to use water with higher concentrations of salt for human consumption. Water used for agriculture may vary considerably in salt concentration, depending on the type of crop being irrigated. Some crops will take a relatively high level of salt concentration and still do well. The fact that some agricultural crops can tolerate higher levels of salt than can be tolerated for certain other uses of water will require cooperation to see that water is properly used.

New methods for handling the return drainage flow from irrigated areas will have to be looked into. The desalination processes may have to be applied to drainage from irrigated fields, thus purifying the water that is used. This, of course, will only be able to be applied to areas where the drainage can be intercepted before returning to a stream. A field that has been tile drained may serve this purpose rather well. Even if these irrigation water problems are worked out successfully, another problem will be disposal of the concentrated materials removed from the water.

Organic Wastes

Many organic wastes are produced by agriculture. Organic agricultural wastes include animal wastes, residue from trash in field and forest, and waste and byproducts from food, feed, and fiber processing plants. Even after being mixed with water, these wastes sometimes emit odors into the atmosphere. They may help to disseminate and even serve as a spawning ground for vermin. One of the most serious sources of organic waste in agriculture is from animals. Although both domestic and wild animals contribute to the problem, we will limit this discussion to domestic animals.

In the *1938 Yearbook of Agriculture* it was estimated that 1 billion tons of manure was being produced annually by livestock on American farms. It was also estimated that this manure was capable of producing $3 billion worth of increased crop production. At the 1970 Conference on the Relationship of Agriculture to Soil and Water Pollution held at Cornell University it was estimated that 2 billion tons of manure were produced in 1970. The drastic change in attitude toward the usefulness of manures has been due to several factors. One of these factors is the concentrated production of livestock and poultry. Large-scale confinement-type enterprises have made it possible to raise, on a few acres, the hundreds of thousands of livestock and poultry that formerly required hundreds or even thousands of acres to produce.

Problems involved in the concentration of the excrements of these animals in such small areas are obvious. What can be done about this is not so obvious. Waste production by domestic animals in the United States is approximately equivalent to a human population of 1.9 billion. Sewage treatment for this volume of waste is almost unimaginable. Another fact is that animal wastes from concentrated production produce waste that is much more concentrated than normal municipal sewage. This is due to the fact that these wastes are not diluted by large volumes of water used for other purposes as is the case with municipal

sewage. Another problem contributing to the buildup of animal wastes is that economic studies indicate that the cost of handling manures is greater than the cost of chemical fertilizers.

At present, domestic animals produce over a billion tons of fecal wastes a year in the United States. Liquid wastes alone amount to over 400 million tons. When bedding, dead carcasses, and other wastes from animals are included, the total animal waste is close to 2 billion tons.

It is possible that half of the animal wastes are produced under concentrated conditions. Cattle in concentrated conditions tend to produce a much higher excrement than average because of the high production for which these animals are being fed. Table I below compares the values of wastes of animals with those of man.

Most comparisons of animal and human wastes in the form of fecal production are based on measurement of BOD. It is important that these comparisons not be made simply on the basis of total fecal production because a high percentage of animal feces never reach water. (The amount of waste that reaches water would be a more relevant comparison.) These comparisons are, however, an indication of the total amount of animal wastes, which may become even more important with the higher concentrations of animals and more concentrated feeds. If present trends of poultry and animal consumption continue, the pollution potential of feedlot wastes will continue to increase. Methods are, however, being developed to help cut down on the pollution of water from feedlot wastes.

Table 1.—Wastes From Domestic Animals

Animal	Animal population (in millions) (1)	Ratio of waste output of single animal to output of a human (2)	Total animal wastes expressed as equivalent number of humans (in millions of humans) (3)
Cattle	107	16.40	1,754.8
Horses	3	11.30	33.9
Hogs	53	1.90	100.7
Sheep	26	2.45	63.7
Chickens	375	0.14	52.5
Total[a]	564		2,005.6

[a]Col. 1 times col. 2 equals total in col. 3

Source: *Environmental Quality: The First Annual Report of the Council on Environmental Quality.*

Even with all the other problems that can come from animal wastes, the major objection from the public seems to be the odor. Odor is a particular problem when water has been overloaded with animal wastes, and bacteriological action changes from aerobic to anaerobic decomposition. Anaerobic decomposition is ordinarily accompanied by the production of vile-smelling gasses and odors. Information as to the exact amounts of pollution being caused by animal wastes is extremely limited at this time. It can, however, be stated that domestic livestock are producing wastes that are to some degree offensive to the public.

Plant residues are another source of organic wastes from agriculture. If plant residues are burned, they produce smoke and other air pollutants, as well as a limited amount of ash and other materials that may be washed into streams. If the plant materials are not burned or otherwise disposed of, they may serve as reservoirs of plant diseases and other pests. The exact effect of crop residues is sometimes hard to estimate. In some cases, crop residues have been used as a mulch and do help to prevent soil erosion and depletion. Since these residues do, however, carry certain plant diseases, these may be carried into rivers and streams and transported great distances. Since plant residues are organic materials, they will contribute to BOD loadings when they are washed into rivers or streams.

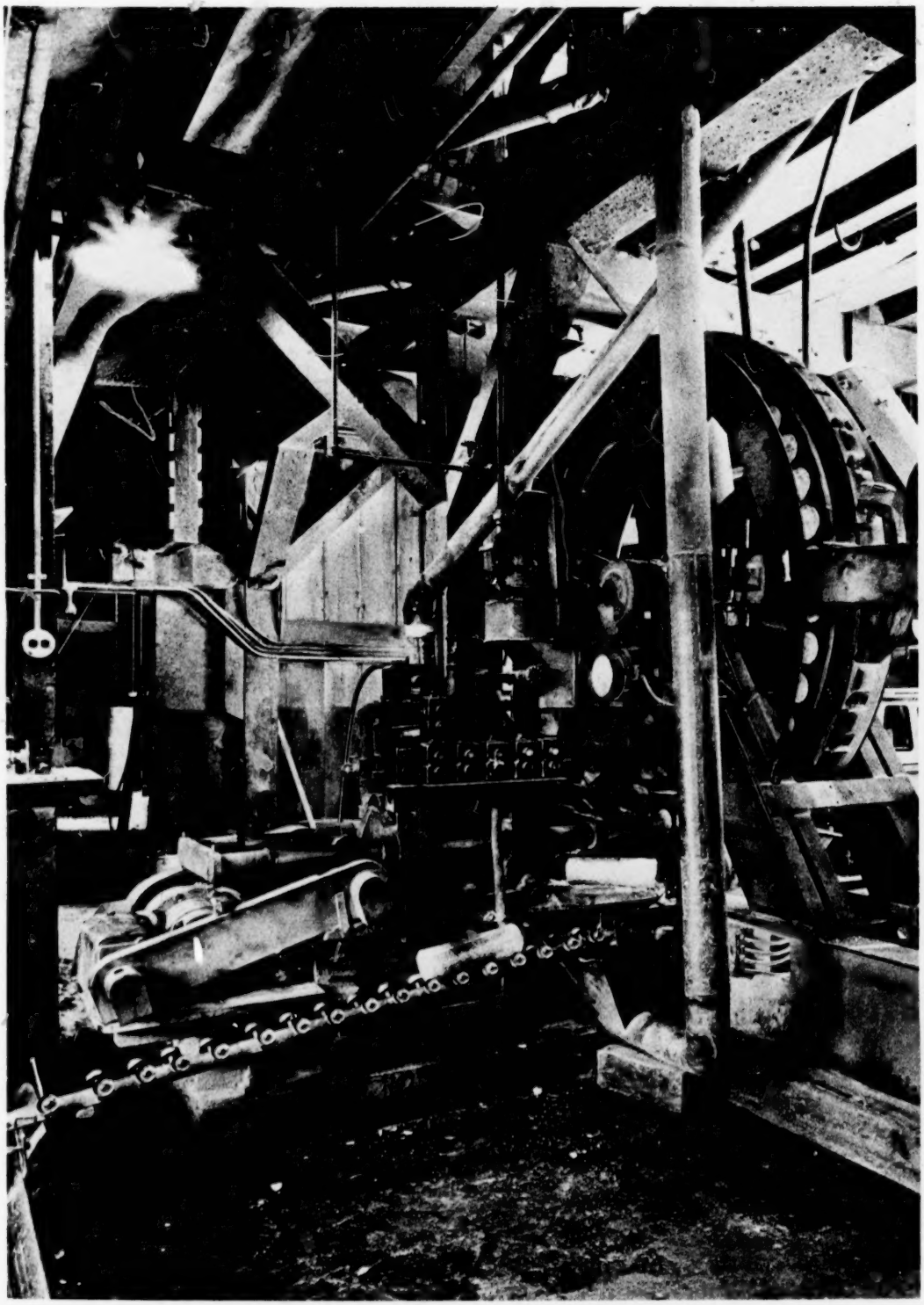
Each year approximately 25 million tons of logging debris are left behind. These materials, called slash, become a fire hazard. Forest fires can be disastrous, followed by many years of severe erosion. Slash material in various stages of decay also may be washed into surface water causing a great deal of water pollution.

Another source of organic waste in agriculture is from food and fiber processing plants. The amount of organic waste pollution from food and fiber processing plants varies greatly. For example, it has been shown that asparagus canning causes less than 100 parts per million of BOD. Pea vine ensilage juice has been reported to have a BOD of 75,000 parts per million. Many kinds of agricultural industries produce oxygen-demanding wastes. These industries include textiles; distilling; sugar refining; manufacturing of cornstarch and soy protein; slaughtering and processing of animals; fruit and vegetable processing; processing of dairy products; sawmilling; pulp, paper, and fiberboard manufacturing; and many others. These wastes, like any other organic wastes, tend to cause severe problems upon entering water. If the concentrations of these wastes are high enough, they make the water dark, foamy, or unattractive in many ways. They make water undesirable through odors from anaerobic activity or from the lack of fish that they produce.

Many statistics could be given to show that damaging wastes are now being given off by food and fiber processing plants. The largest pollution potential from BOD is from the wood pulp industry. Potential BOD requirements of the effluent from wood pulp, paper, and paperboard industries are greater than those of the raw sewage from all the people in the United States. Pulp and paper manufacturers are making a determined effort to reduce water pollution in their manufacturing processes (fig. 7).

Chemicals

Properly used, pesticides have resulted in great benefits to man (fig. 8). The question here, however, is not how much benefit has been derived from the use of agricultural chemicals but rather how much damage has been done by them. Most experts seem to agree that, when properly used, agricultural chemicals have resulted in benefits much outweighing any harm. On the other hand, when misused or used carelessly, they have caused considerable harm. There is little argument that agricultural chemicals are a source of pollution.



Weyerhaeuser Co. Photo by J. Fardell

Fig. 7.—Sawdust turns into fireplace logs at Longview.

You, the user, are the last word in avoiding accidents!
Agricultural chemicals—like medicine—should be used and stored according to directions.
Here are four keys to remember when using any pesticide:

(1) READ THE LABEL—and follow instruction exactly.
(2) USE it properly—keeping children and pets well away.
(3) STORE it behind lock and key—never in things like pop bottles.
(4) DISPOSE of "leftovers" and empty containers properly—immediately.

Source: National Agricultural Chemicals Association

Fig. 8.—National Agricultural Chemicals Association Pesticide Poster

The use of agricultural chemicals continues to increase; 693 million pounds of pesticides were sold in the United States in 1964. Forestry and agriculture accounted for the use of 65% of these materials. A study conducted by the United States Department of Agriculture estimates that farmers spent $514 million for pesticides in 1964.

Many acres are being sprayed annually by airplane and helicopter. This allows for rapid application of chemicals in areas such as forests where other methods of application are nearly impossible (fig. 9).

Insecticides are probably the most important group of pesticides. This is due to the fact that they are highly toxic materials intended to kill insects. Many of these highly toxic materials are not highly selective as to the type of animal life they affect. Some are also very persistent. That is, they tend to break down very slowly and so continue to have an effect on the environment for a period of time after their usefulness for the purpose for which they were applied has expired. Some of these insecticides accumulate in animal tissues and may affect reproduction, even at fairly low levels of residues in animal tissues. The persistent chlorinated hydrocarbon insecticides are one of these most-feared groups of chemicals, and DDT is a member of this group.

USDA Photo

Fig. 9.—Downwash created by helicopter rotors ensures safe and effective penetration of spray material.

DDT residues have been found in soils and also in the tissues of man, fish, wild animals, and birds. The importance of these residues at the levels at which they are found has not been established. DDT residues have been found to exceed 100 pounds per acre in some orchards. Varying levels of residues of other insecticides such as endrin or dieldrin have also been found both in crops and in soils. The average level of DDT-derived materials carried in human body fat in the United States is 900 milligrams. This figure seems to have remained relatively constant for the past several years. Most experts consider this level to be of no significance to health.

Fat-soluble pesticides appear to be an even more important problem in that biological magnification of residues occurs in the tissues of animals. This happens when organisms containing an accumulation of DDT are consumed by fish, birds, or other animals. The more of these DDT-containing organisms consumed, the higher the DDT content may become in the consumer. Although the accumulation of DDT may not be serious to the organism being consumed it may produce highly toxic results in the organism that consumes it. For example, earthworms that are living in DDT-contaminated soil and then eaten by robins may kill the robins. Many conservationists are very concerned with this problem.

Another important group of materials is fungicides. Fungicides are a group of materials used to destroy or control fungus. Since these materials generally are not highly toxic, the danger of water pollution contamination by them has been considered to be very insignificant. However, recent scares about certain heavy metals such as mercury and copper, both of which are used as fungicides, are causing increased research. Mercury has been used quite widely as a seed treatment. The amounts put on the seed are relatively small. It is, however, thought that even these relatively small amounts may be highly detrimental since many fish and other aquatic life have been found to contain relatively high levels of mercury. The high concentrations of mercury found in some fish are likely due to biological magnification. Natural levels of mercury in ocean waters have not been determined.

Another group of agricultural chemicals that may cause water pollution is herbicides. This group of agricultural chemicals may have very serious indirect water pollution consequences. For example, certain herbicides control almost all vegetative growth. In fact, the soil may be sterilized by use of certain herbicides. The resulting sterilization and lack of vegetation may in turn cause considerable erosion. This erosion may wash both the herbicides and silt into surface waters causing severe water pollution problems.

The use of herbicides for the control of aquatic weeds is subject to regulation and restriction. No organic herbicides are registered for use in reservoirs or lakes used for drinking water. A few herbicides are registered for use in water that is used for irrigation. Control of aquatic weeds in water used for irrigation improves the ability of the water to be moved. Many common herbicides used at proper levels to control most submerged aquatic weeds do not injure fish. The same materials at higher rates may become toxic to humans, fish, livestock, wildlife, and crops. Some materials such as Dalapon and Fenac do not harm fish even at concentration levels far in excess of those required for aquatic weed control. It should be pointed out that some herbicides used at levels necessary to control aquatic weeds are highly injurious or deadly to fish. The importance of correct use of herbicides as well as pesticides is therefore obvious. Some of these materials will injure only certain fish. For example, copper sulfate will not normally injure bass, bluegills, and certain other fish but may be highly toxic to trout at concentrations necessary to control algae.

Nematocides are a group of materials used to control nematodes. Some of the major nematocides presently in use are the halogenated hydrocarbons, carbomates, and orangophosphates. Runoff from fields treated with nematocides or irrigation water that has had nematocides added to it are potential hazards. Chlorine and bromine residues persistin soil that has been treated by certain nematocides. The amount of runoff from soils that have had nematocides applied to plants growing on them has not been determined to date. At this time, no immediate health hazards are apparent.

RESULTS OF WATER POLLUTION

The previous section has shown us that water pollution comes from a great many sources. This great number of sources affects waters in a great many different ways. The complication is increased when the effects on man are considered. Some of the effects on man may be rather subtle. For example, long-term changes in the aquatic life of a river or lake may affect the types and growth of fish in the river or lake. On the other hand, the form of pollution may not be so subtle but may appear as an oil slick or a public health notice that water should not be used for drinking or even swimming.

Damages to Health

In communities across the United States, water coming from faucets may prove to be a direct threat to human health. The threat of epidemics of typhoid, dysentery, and salmonellosis are no longer very serious in the United States. Some diseases, however, have not been very well controlled. An example is infectious hepatitis, which is spreading at an alarming rate in the United States. The major suspect of infectious hepatitis is contamination from sewage. Drinking water in many cities has been used several times before being used in that city. The writings on washroom walls along the northern part of the Mississippi River say "Flush the toilet, they need the water in St. Louis." This statement is not so humorous if you live in St. Louis or many other cities that are in the same situation. Fortunately, many of these cities filter and chlorinate their water and, through this process, should make it safe to drink. Many cities do not treat their water in this fashion, and many do not have safe drinking water. Many United States cities receive their water from sources that are not too pure. Many cities do not protect their water quality throughout the system until it reaches the tap. The water in many cities contains high levels of dangerous bacteria. Some of these bacteria may have come from sewage or animal wastes. Some cities have unusually high levels of chemical impurities in their water. The exact health hazards being caused by these chemical impurities is not known. However, many experts are very concerned about chemical impurities, particularly the effects over long periods of time.

Many questions are also being asked about the safety factor of using chlorine. The questions here are twofold. First, is the use of chlorine safe for human consumption? Many geneticists are asking that chlorine be listed among the materials that need to be more thoroughly researched. It has been suggested that chlorine may at some levels of treatment cause mutations. The other question is whether or not chlorine is doing an adequate job in the processing of drinking water. It is possible that high concentrations of organic matter in the water may allow some viruses to escape treatment by the chlorine. Filtering should

remove particles of this size. It would seem at this time that, due to the high level of dangerous germs in many water supplies, we have little choice but to continue the process of chlorination.

In some areas, municipalities have outgrown their sewage treatment facilities or they may never have had adequate ones. In rural areas, septic tanks may be located too near water supplies or wells. Since water in rural areas is seldom treated in any fashion, sewage may be leaking into underground water that is used for human consumption.

Another major problem is that of nitrate pollution. A major source of nitrate pollution is from sewage. Agricultural production also contributes to the problem of nitrate pollution. Nitrates themselves are not particularly dangerous. However, when certain bacteria are present in the digestive tract, nitrates can be converted to nitrites. Nitrates may also be converted to nitrites in open containers of food and in certain types of feed.

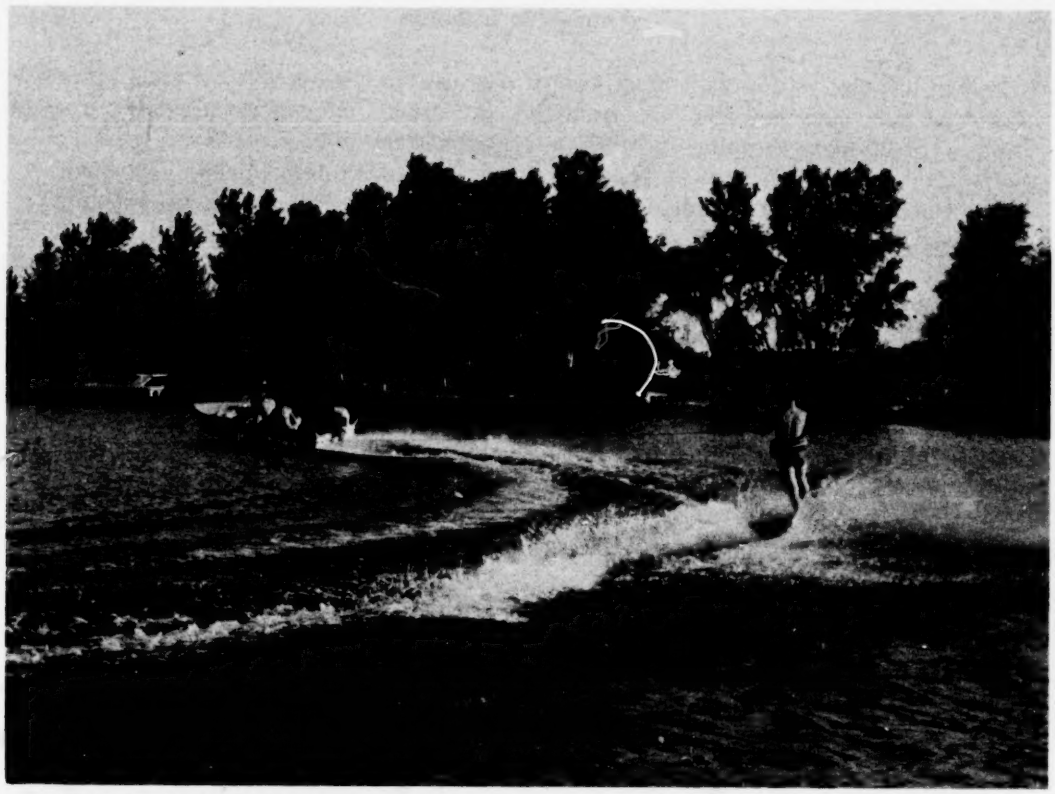
Babies and farm animals are most likely to include in their digestive tracts the types of bacteria and other conditions that help to convert nitrates to nitrites. The oxygen-carrying pigment of red blood cells reacts with the nitrites absorbed into the blood stream. In this process, methemoglobin is formed. This material does not have the ability to transport oxygen like normal hemoglobin. If enough of the nitrate is absorbed in the blood stream, methemoglobinemia takes place. This disease is often referred to as "blue baby" since infants turn particularly blue because of the lack of oxygen. Methemoglobinemia is characterized by labored breathing and in extreme cases may terminate in suffocation. The importance of "blue baby" can be readily seen by the fact that 139 cases were found in Minnesota from 1947 to 1950. Fourteen of these cases resulted in the deaths of the infants.

As the population of an area increases, the cost per capita of avoiding water pollution also tends to increase. This makes large cities a very expensive operation. Many of the larger cities are contemplating sewer and water system costs and treatment facility costs in excess of millions of dollars. Increased research will be required to help improve the quality of water. We presently have the technology to maintain safe bacteriological quality and to remove many of the potentially dangerous chemicals from the water. However, in many areas, what we now know is not being effectively used or employed.

Damages to Recreation

Recreation influences physical and mental health and is a necessary part of our lives, but many things have happened to change the significance of recreation in our lives. Increases in leisure time have allowed us more time to travel to parks and recreation areas (fig. 10). The growth of cities with the process of urbanization has increased the appreciation of recreation areas away from the cities. The speed of modern life and changes mentioned above, along with some other changes, have made recreation an even more important human value.

Park and Recreation Guidelines, a publication for the State of Washington, lists 10 contributions of recreation to individuals: relaxation, adventure, self-expression, beauty, knowledge, morale, social adjustment, character, skill, and physical fitness. The opportunities for this type of recreation can be diminished or halted as a consequence of water pollution. For example, beaches may have to be closed by public health authorities when bacterial counts reach certain levels. Inadequately treated wastes from municipalities are the principal bacterial polluters in high-population areas. In rural areas, animal wastes may become serious problems by raising bacterial counts in waters that could otherwise be used for swimming. Boating and waterskiing may become unpleasant due to floating solids,



USDA Photo by B. C. McLean

Fig. 10.—This area was developed by a local owner using abandoned sand pits. The 30 acres of water make for good fishing, water skiing, and other recreational activities.

gas bubbles, odors, and plant growth. If the bacterial levels are high enough, water pollution can become a health hazard and eliminate boating and waterskiing. Fishing can be very severely damaged by poor water quality. Some of the most desired types of game fish require the highest quality of water. Fish often die as water quality declines. Often less-desirable species then take over. The trout is an example of a fish that requires cold water and high dissolved oxygen levels. This means dissolved oxygen levels in excess of five parts per million. It is obvious that control of both thermal pollution and BOD wastes are important to keep trout as a sport fish. Undesirable fish such as the carp can live in warmer water and with dissolved oxygen levels below four parts per million. These "trash" types of fish can live for short periods with less than two parts per million of dissolved oxygen.

Although fish can die from all types of pollution, the majority of fish kills are caused by three types of pollution. These are the lack of dissolved oxygen, the presence of pesticides, and the presence of toxic wastes from industrial operations. Over 70% of the fish kills in 1969 were caused by industrial wastes. Approximately 20% of the fish kills were caused by agricultural wastes. Most of the fish that were killed in 1969 were the least desirable fish and were living in these areas because they were already tolerant of water pollution.

Damages to Esthetics

Man has always derived a great deal of pleasure from water. Pleasure has come from food that the water supplied him; from the cool drink that satisfied his thirst; from the cleansing of the body, clothing, and other materials; and from his use of the water as a means of transportation and for power. Man has also derived pleasure from simply being near the water. He has appreciated walking beside a clear pool, watching a fountain, relaxing on a lake shore or along the ocean, or just identifying with a majestic body of water such as the Great Lakes or San Francisco Bay. The esthetic aspects of water have been important to man throughout history. Man has enjoyed the esthetics of water for picnicing, walking, hiking, bicycling, or just driving near the water's edge. Man's use can quickly change the esthetic qualities of water. Pollution has killed fish. These sometimes wash to the shore where they cause unpleasant odors. Other unpleasant odors have also existed, some of these due to a high BOD content in the water. Plants growing in the water can also become detrimental to the esthetic qualities of a lake, river, stream, or pond. Sediment may fill in a water body or turn its waters murky brown, reducing its beauty.

Damages to Fishing

As has already been mentioned, sport fishing provides an important source of recreation to many persons. Commercial fishing is an important industry to many areas of the country. Proceeds of commercial fishing in 1968 amounted to approximately 4.9 billion pounds of fish or shellfish with a value of $354 million. The following year, fish and shellfish production fell to 4.3 billion pounds, but the value increased to $518 million. The extent to which this lowering in amount of fish is due to water pollution is not known. It has been shown that some of the damage is due to sediment (fig. 11).

Damages to Agriculture

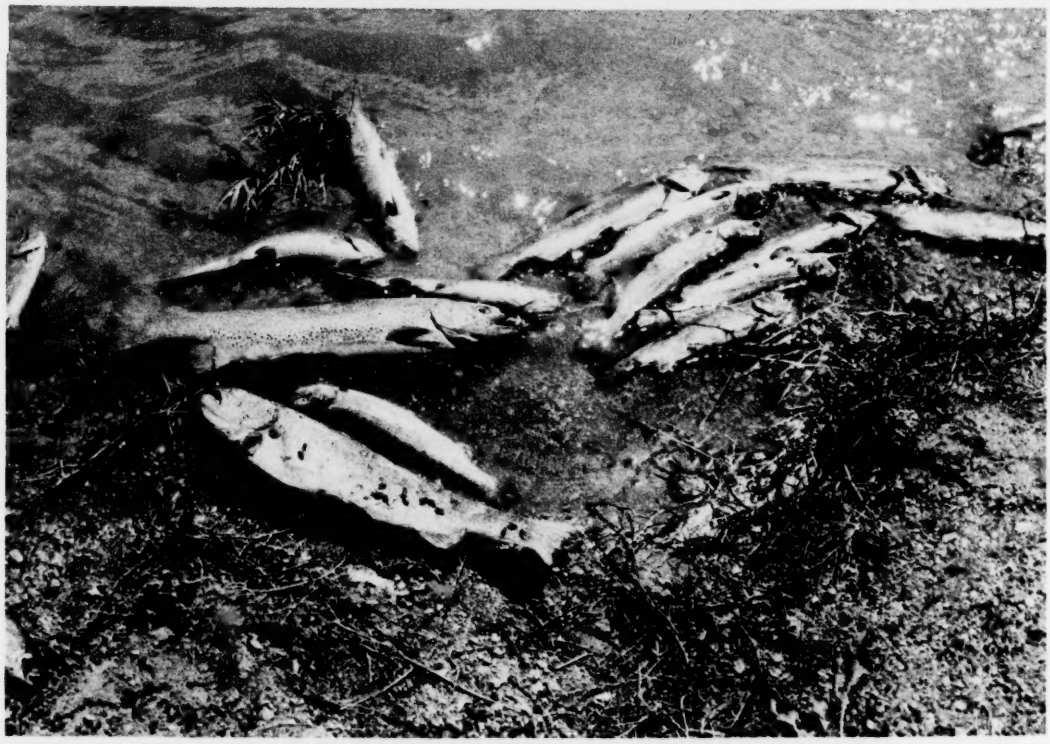
Probably the most important water quality problem that affects agriculture is saline pollution. As water evaporates and is used by plants, salt concentration rises. This becomes particularly true when water used for irrigation is reused several times.

Organic wastes may affect agriculture in many ways. Recreational activities associated with agriculture and forestry operations may be severely affected by organic wastes. If a stream being used for recreational purposes is polluted by large dumpings of organic wastes it may completely eliminate fish. Swimming, boating, and other recreational activities involving the water may also be curtailed or halted. Recreational activities relating to agriculture and forestry have become multi-million-dollar industries. Organic waste pollution could have serious effects on such activities.

Water that is polluted with unassimilated organic wastes may not be usable at all in the production of certain food crops. Pollution from organic wastes may make rural water supplies unusable. Organic wastes such as manure heaps, piles of crop residues, and accumulations of food processing wastes may be sources of both underground and surface water pollution (fig. 12).

Some agricultural producers have been judged by the courts as "noncompatible" with the activities of an expanding metropolitan area. Judgements such as these have forced a number of agricultural producers to move their businesses. The cost of moving a business

USDA/SCS Photo by R. T. Thompson



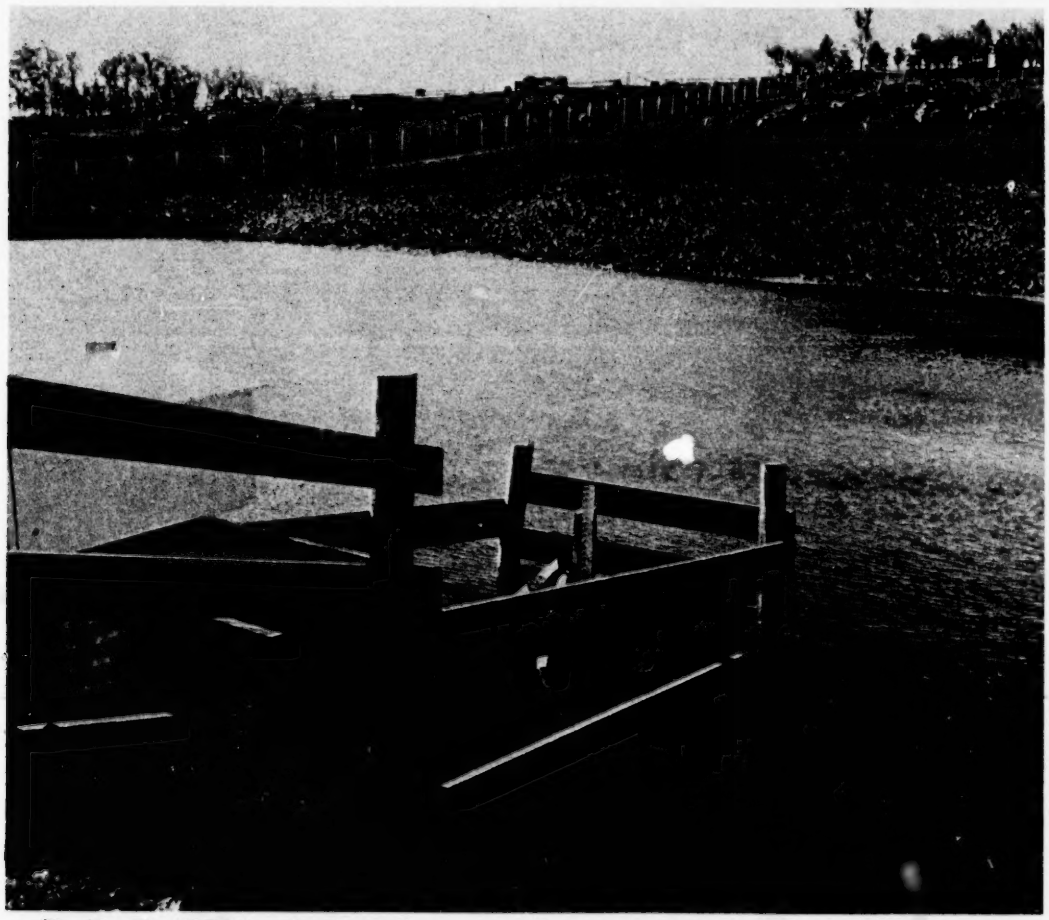
USDA/SCS Photo by E. W. Mustard

Fig. 11.—Sediment fills streams and kills fish.

such as a dairy farm may easily reach $100,000. Feed lots are another group of agricultural businesses having suits brought against them in an effort to prevent or curtail water pollution.

Infectious agents, such as bacterial and fungus diseases, are generally carried by wind, water, and soil. These infectious agents may have very adverse effects when water carrying them is used for irrigation. Nematodes (long, round worms) may move from one infested area to another in water, thus, irrigation may spread them. Infectious agents can also be spread by water. The virus causing hog cholera may be picked up from polluted water. Brucellosis of cattle, swine, and goats may be spread by water. Stagnant waters may provide the breeding ground for disease-causing organisms as well as for insects that may spread disease-causing organisms.

Although the amount of damage done by water-spread infectious agents is not known exactly, it can easily be seen that this can amount to large annual losses. For example, if only a very small percentage of the billions and billions of dollars worth of animals and crops are affected by waterborne infectious agents, the losses that occur could be estimated to be millions of dollars per year.



USDA Photo by M. Lemmon

Fig. 12.—The USDA has placed sampling and recording equipment in this feedlot catchment pond to determine new ways to prevent pollution.

Water may also be contaminated with weed seeds. If water contaminated with weed seeds is used for irrigation, thousands of acres of irrigated land may become reinfested with weeds. A parasitic plant called witch weed produces thousands of microscopic seeds. These seeds are easily disseminated by water. Something that is this easy to disseminate is very costly to quarantine or irradicate. Many weed species are poisonous to humans, livestock, birds, and wildlife. Each year farmers spend approximately $2½ billion to control weeds. This seemingly astronomical figure is only part of the cost of weeds since both crop yield and quality may be reduced by weeds. Average annual crop damage due to weeds may range from less than 5% to 25%, depending on the location of the field, type of crop, and types of weeds.

Chemicals may adversely affect agriculture as well as individuals, industries, and others. If sewage contains nonbiodegraded detergents and is used for irrigation, the rate of infiltration of water into the soil may be lowered. The adverse effects of detergents on agriculture have not been fully explored.

Although insecticides have brought many benefits to agriculture, there are also instances where they have adversely affected agriculture in other ways. Since most insecticides are not highly specific in their ability to destroy insects, they may destroy beneficial insects as well as those that are being controlled purposely. For example, malathion helps tc control and irradicate numerous insect pests, but it also destroys large numbers of honey bees and other insects that help in crop pollination. Residues of pesticides have been found in agricultural crops grown in fields in which pesticides had been applied in previous years to another crop. Residues have also been found on agricultural crops as a result of accidental contamination, inadvertent use, or drifting or, in a few instances, even after pesticides are used following instructions. Losses to producers for crops that have been condemned may be very serious.

Fish have been killed in farm ponds because of drainage of insecticide wastes from nearby lands. Some insecticides that have been applied to rangelands have later been found as residues in the meat of beef animals. Aldrin and heptachlor are two such pesticides. Since residues of such pesticides are not allowed in beef animals, Aldrin and heptachlo are no longer registered for application on rangeland. Improper use of insecticides, disposal of leftover insecticides, and disposal of insecticide containers have resulted in injuries and caused a few deaths to applicators of such materials. Application of pesticides may also cause hazards for field workers.

Spray drift vapors from the application of herbicides being applied to control weeds or brush may cause damage to crops, flowers, ornamental plants, and trees. The amount of damage done may be due largely to timing. For example, herbicides used to kill weeds in lawns may do severe damage to shade trees such as maples in the early leaf stages of growth. Applications of herbicides either earlier or later than this stage may do much less damage. Herbicides that have been tested and used very safely under one set of environmental conditions for a specific crop may, under different environmental conditions, cause serious damage.

The economic effect of small pesticide residues could become much more serious. For example, small quantities of food crops have been taken from the market through condemnation procedures in the past several years. When such events are publicized, consumer acceptance and consumption of these products could be diminished.

Sediment poses many problems for agriculture. It fills stream channels, irrigation canals, farm ponds, and reservoirs (fig. 13). Sediment may impair water for use for irrigation, recreation, fishing, and farmstead water supply. Sediment in water used for irrigation may cause abrasion of irrigation pump parts. Sediment suspended in water impairs the dissolved oxygen balance and thereby limits the water's ability to break down other oxygen-demanding wastes. Reduced oxygen in the water also damages fish life. Recreational activities are seriously affected as sediment increases.

The useful life of farm ponds can be drastically cut because of sediment accumulation. Overwash of infertile material may impair natural drainage and growth characteristics of other soils.

River waters that contain 750 parts per million of dissolved salts, a rather moderate level, will produce approximately 1.2 tons of salt per acre-foot of water applied for irrigation. Fields that have salty irrigation water applied to them may be hurt by the salt concentrations. If the salt residues become great enough, or if improper management practices in leaching and draining the field are practiced, the crop may be virtually eliminated. Crop growth may be stunted even at moderate levels of salinization. The type of salt may be of just as critical importance for agricultural use as the total amount of salt content.

For some municipal and industrial uses, it is necessary to soften the water supply. In this process, calcium and magnesium are replaced with sodium. Obviously, the waste water will be enriched with sodium in place of calcium and magnesium, so the quality for agricultural use will be much lower in value.

USDA Photo

Fig. 13.–Sediment is filling thousands of ponds, lakes, and reservoirs every year.

Approximately 25% of the irrigated lands of the United States are affected to some degree by salinity. If present trends are to continue, this problem will become even more important in the future. Using salts to melt snow on highways has become a serious problem in many states. Salt running off highways has damaged many types of vegetation. Water sources and supplies have also been contaminated by this runoff of salts from highways. If salt levels continue to rise in waters used for irrigation, farmers may be forced to raise salt-resistant crops that may be of lesser economic value and be less desirable to the consumer.

The first time water is used for irrigation quite drastic changes may occur in composition as well as concentration of dissolved salts. This may have considerable effect upon re-use of the water for other irrigation projects. Although most crops tend to exhibit decreased growth and yield with increasing salt levels in the water supply, each type of crop has different tolerance levels to different kinds of salts. It is therefore impractical to try to set a single level of salt concentration that is damaging to crops. Many other factors also affect the salt levels that can be used for irrigation, including management, soil, and climate.

Some salts also have other severe effects on soil; through continued treatment with these salts, the soils may become highly impermeable. This is often true with water that has been softened for metropolitan use. In addition, the sodium used to soften the water may also be toxic to woody plants.

As strange as it may seem, plant nutrients may have some detrimental effects for agricultural users. For example, plant nutrients can produce plant growth in farm ponds that will make the pond less usable for recreation. If plant growth becomes lush enough, the ponds may become less desirable for irrigation. Plant growth may reduce fish production, impede boating and swimming, and provide a good habitat for mosquitoes and snakes. After plants die, their decomposition will require high amounts of oxygen. If this becomes a serious enough problem, the type of bacterial action may change from aerobic to anaerobic, thus producing offensive odors, bad tastes, and undesirable visual effects and possibly seriously affecting fish life.

Another serious problem for agriculture is the growth of aquatic plants in canals and ditches. The growth of aquatic plants may impair and clog the canals and ditches used for both irrigation and drainage. The reduction of the capacity of the ditch may have implications beyond that of agricultural production since it may contribute to flooding. A major item of cost in the maintenance of ditch drainage is the control of aquatic weeds.

As has already been discussed, concern is mounting over nitrate pollution. Besides the deaths and illnesses that can be caused by nitrate poisoning, examples of high rates of abortion in sheep, cows, and other animals can be cited as a serious problem. Infant methemoglobinemia (blue baby) is particularly important to persons in agriculture since a majority of deaths from this condition have occurred in infants drinking rural well water. It has also been noted that while adults drinking this well water may not be affected, breast-fed infants of mothers drinking such water may be poisoned. Infants may also be poisoned by drinking cow's milk produced while the cow is drinking water sufficiently high in nitrate.

Another plant nutrient that is beginning to worry some experts is boron. Boron is an essential element for plant growth but is needed in very small concentrations for most plants. Lack of these small concentrations of boron show up readily in such crops as cauliflower. When cauliflower which has been deficient in boron is cut the stem is hollow. If the deficiency has been serious enough, the cauliflower head will rot. On the other hand, even very small concentrations of boron may be very injurious to many plants.

Concentrations of boron may be even more important in the future as it is used for industrial processes. Boron has also been used as an additive in detergents, hand-washing soaps, and other compounds. Boron from these sources may add enough to waste water to preclude use of this water for agricultural purposes. Boron may also limit the usefulness of water for supporting growth of native or ornamental plants.

Although thermal pollution is having great significance for most other areas, thermal pollution seems to be of minor importance for agricultural use at this time. It may be that the greatest agricultural effect of thermal pollution will be in the area of recreation where agricultural lands are being turned to this use. This is most likely to be particularly true where fishing is part of the recreational activity.

Damages to Water Supplies

Many industries now treat water before they use it. In some industrial processes, such as the production of fine papers, extremely pure water is a necessity. In other instances, water is treated simply to attain constant quality levels which in turn help ensure quality control in the product. The lower the level of pollution of the water source, the cheaper it usually is for industry to pretreat the water for their use.

Many drinking water treatment plants do not remove small amounts of potentially toxic materials. The effects of these potentially toxic materials are not well known. It is known, however, that treatment of polluted waters for drinking or domestic uses does not increase the cost. To meet current standards for domestic uses, the cost of treating polluted water is not significant. Pollutants that affect the taste and odor of water may cause serious problems. Algae growing in the water may affect taste or give off odor.

People are often reluctant to use polluted water sources for drinking or domestic uses even after treatment. The quality of water taken for use in some large cities is approximately equivalent to that of the Hudson River near New York City. Because of the familiarity with the pollution that has taken place in the Hudson River, many persons are not excited about the prospects of using it as a source of drinking water.

Control

Large amounts of money are needed to clean up polluted waters. Projections of exact costs of water pollution abatement are extremely difficult since many alternatives may be chosen. At present, there is wide variation of opinion as to what should be established as desirable water quality objectives. Assumptions, estimates, and projections of what is necessary, desirable, or possible in water pollution abatement are likewise diverse.

With this brief introduction to the hazards of prediction, a few estimates for the future will be discussed. For the period from 1972 to 1977, it has been estimated that more than $2 billion per year will be required to construct municipal waste treatment plants to meet water quality standards. Operating costs of these treatment facilities will probably nearly double during that time. The American Public Works Association has estimated that the costs of dealing with the problem of combined sanitary and storm sewer overflows are between $15 and $48 billion. For a city the size of Chicago it has been estimated that the cost of dealing with combined sewer overflows could easily exceed $2 billion. Total pollution abatement facilities for many new industrial plants are costing up to several percent of the total cost of construction. Industrial abatement costs for water pollution in the 1972-1977 period, excluding waste heat for power production, are estimated to be well

over $3 billion. In the same period, it is estimated that industrial costs may increase 50%, and recirculation of water to prevent thermal pollution could require an estimated $2 billion. Each of these estimates is obviously based on many unknown factors.

PRESENT SITUATION

Problems and Their Control

The two major sources of organic pollution are industrial and municipal wastes. Industrial discharges contribute three to five times the waste load of municipal systems. Technology is presently available to greatly reduce water pollution from industrial sources. In many industries, the problem is to find enough money to do the job. There is little doubt that industries are increasing their investments for water pollution control facilities. This is due in part to the minimum standards set by governmental agencies. Many industries are carrying on voluntary research to improve pollution control facilities. While some firms are doing a fine job of research and pollution prevention others are lagging behind. It seems likely that the firms that are lagging behind presently will require increased Federal and State enforcement for them to improve their water quality standards.

Estimates of the Environmental Protection Agency (EPA) are that over $13 billion will be required in capital investments between 1971 and 1976 to work toward the solution of water pollution problems. Of this, $10 billion would be required for capital investments in municipalities to provide sufficient water quantities at required water quality standards.

The American Public Works Association estimates the cost of dealing with the problems of combined sewers will cost $15 to $48 billion.

One reason that industry's capital outlay cost is not as high as for municipalities is that they do not have the great land areas over which to collect wastes. Industrial abatement costs, excluding those for waste heat for power production, are estimated at $3.3 billion between 1971 and 1976. Operating costs will also increase from $515 million in 1969 to $715 million in 1974. Up to another $2 billion would be necessary between 1971 and 1976 to provide recirculation of water to prevent thermal pollution.

At present, measuring procedures are not adequate to accurately say whether water quality is improving or not in a given body of water. There are a few examples like Lake Washington in Seattle which have shown dramatic improvement. In certain other areas, dramatic deterioration can be seen. Given the present interest in environmental quality at Federal, State, community, and industry levels, and with increased cooperation and financing, improvements should be more numerous in years to come.

Nutrient Enrichment

One of the major water pollution problems is that of eutrophication. What makes this problem very serious is that eutrophication does not stop when nutrient enrichment ceases. The causes of eutrophication have been questioned in recent years. Some people have claimed that carbon was stimulating algal growth. The Department of Interior has concluded that phosphates are the most important nutrients causing eutrophication. The exceptions to this and where carbon might be most important are where algal blooms are already at an unacceptable level. In certain areas of the West, such as the Palouse country, phosphates are abundant naturally in the soils and nitrogen will normally be the limiting nutrient.

The largest single usable source of phosphate is from municipalities. A large portion of these phosphates from municipalities come from detergents. Approximately 50% of the total phosphates are from detergents. Another source of phosphates that may be even more difficult to control is from runoff of phosphate fertilizers. As was mentioned earlier, phosphates tend to combine tightly with soil molecules, thus limiting their availability and making them resistant to runoff. Another contributor to eutrophication is nitrogen. This is a particularly important nutrient contributing to eutrophication in the western part of the Unites States. Nitrogen also originates from municipal discharges and fron runoff from the land.

Toxicity Levels

Mercury pollution has become a serious national problem. Exotic wastes, which are potentially toxic to human and aquatic life, are being created by increasingly complex manufacturing processes. This plus increasing industrialization and urbanization are rapidly adding to the problems of water pollution. Levels of many heavy metals are rising. The long-range effects of these heavy metals and pesticide residues are not well known. Although research on pesticides and other exotic materials is being carried out, more needs to be done, particularly in determining long-range effects.

An awareness by the public and better research methods have changed the purposes for which many materials may now be used. New measuring processes and devices have allowed scientists to measure toxic residues with far greater accuracy than was thought possible even a few years ago. Some toxic materials are now being measured in parts per trillion. In some cases, this makes the measurement of toxic materials practicable where a few years ago traces of the same material could not be found.

Waste Heat

There is rising concern over thermal pollution of waters. Production of electric power is the source of great quantities of thermal pollution being poured into our Nation's water. The electric power industry is a rapidly growing industry. This is necessary to meet the ever higher power demands of the American people. Although large new hydroelectric power generating facilities are being built, the trend for the future is toward nuclear plants.

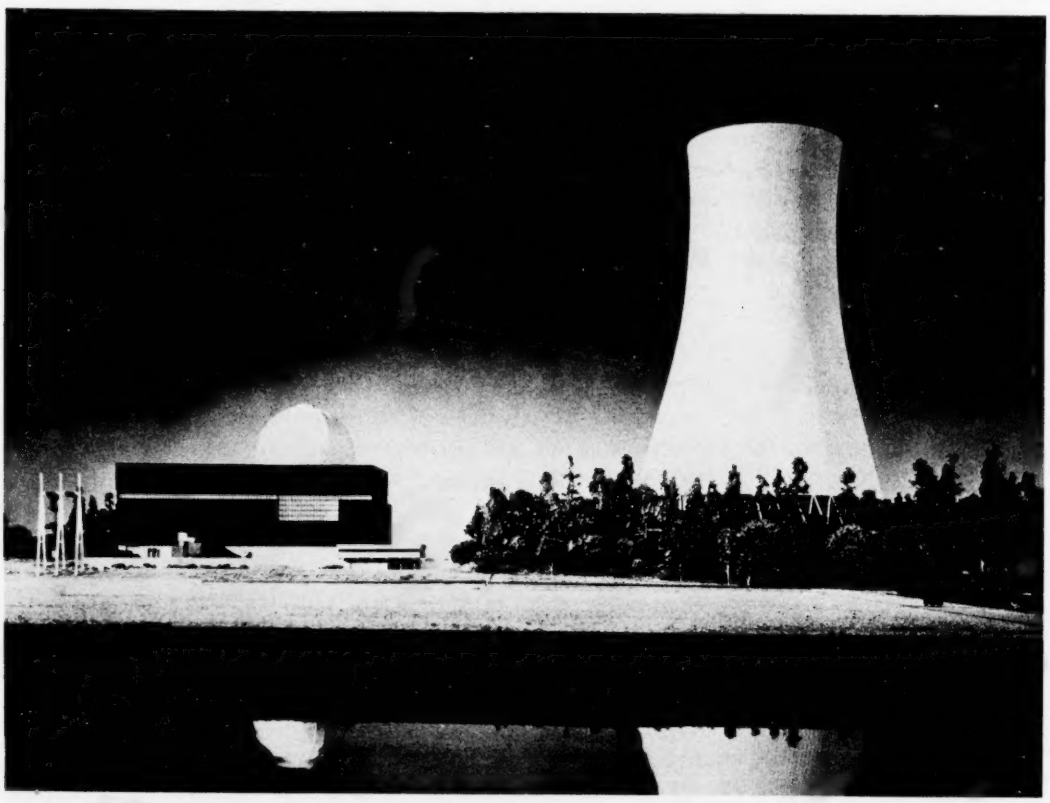
Nuclear plants produce 50% more thermal pollution than fossil fuel plants. If uncontrolled, the continued increase in nuclear powerplants could create tremendous amounts of thermal pollution. Fortunately, the tremendous thermal pollution potential of projected power can be controlled to reasonable levels. Plant efficiency can be increased thus reducing thermal pollution. Waste heat may be used for other purposes. The heat may be dissipated by the use of cooling ponds, spray ponds, or cooling towers (fig. 14). The productive uses that can be made of waste heat will require further research.

Governmental Programs

The Federal Government has had limited authority to set and enforce water quality standards. This authority has covered only interstate waters for the most part. There is little argument that Federal authority inadequately covers intrastate and ground waters. Agencies within the Federal Government have duplicated services. In some cases, Federal agencies overlapped, and in other areas there was a lack of jurisdiction. The number of agencies

involved in many water pollution activities prevented any particular agency from exerting broad jurisdiction. Many States have also had poorly spelled-out water quality controls. Federal Government jurisdiction has been limited, except for shellfish damage or for oil and vessel pollution, to two types of cases under the Federal Water Pollution Control Act. These are if the pollution from one State is endangering the health and welfare of another State or if the governor of the State in which pollution occurs has requested Federal help. Also preventing reasonable enforcement has been the fact that the procedures have been cumbersome and time consuming. In the past, the Federal Government's only weapon in the fight against pollution has been the court cease-and-desist order, the court could take contempt action. In the Federal Water Pollution Control Act, there is no authority or provision for fines to enforce compliance of water quality standards.

Much new Federal legislation has been passed and more is being discussed. This legislation either has or likely will extend jurisdiction of Federal agencies, mainly the Environmental Protection Agency, to include State problems. Specific guidelines of requirements and enforcement procedures will be established. Fines will be established for noncompliance. Voluntary compliance is the main purpose for the enforcement program. Enforcement by power of all the necessary pollution regulations is impossible. There are not enough persons available in the Environmental Protection Agency to even inspect all the possible areas of water pollution. The problem would become even more severe if these persons were expected to file time-consuming reports and follow time-taking procedures in



Portland General Electric Co. Photo

Fig. 14.—The Trojan nuclear plant located 4-1/8 miles southeast of Rainier, Oregon, is expected to be completed in September of 1974. The cooling tower at right of picture will be 499 feet high and 385 feet in diameter at the base.

enforcement. What is needed is clearer guidelines stating time schedules and types of enforcement for municipalities, industries, and agriculture. Penalties for noncompliance also need to be clearly stated.

Even with the enforcement problems of the past, many industries and State and local governments have made improvements. It is becoming increasingly obvious to all these groups that the Federal Government intends to become more vigorous in its enforcement of water-pollution laws.

Many States have large-scale water-pollution agencies presently at work. Most of these have been unable to meet the tremendous challenges of attaining good water quality standards. Most of these States have had a rather severe shortage of finances and personnel. Low salaries and meager promotional opportunities have discouraged some talented persons from seeking employment in water-pollution control agencies at the State or local level.

In many areas, there are many water treatment facilities that are too small. In some areas, there is no treatment facility or a vastly inadequate facility. The local independent forms of government plus Federal grants have encouraged the building of many small sewage treatment facilities. A regional organization with a much larger facility could be operated more economically because at least one operator is required at most treatment plants regardless of size. Second, a better job of pollution control could be carried out. Better pollution control is likely to come about on a regional basis because there will be fewer areas that have inadequate treatment facilities. Also, more skilled personnel can be hired for better operation of treatment facilities.

Local treatment facilities also lack manpower and financial backing. Inexperienced personnel with poor training contribute to a suprisingly large number of poorly operated treatment plants. Not only is the plant treatment ability reduced, but also the useful life of the plant may be shortened. Courses to train treatment plant operators are becoming more prevalent. Many types of educational institutions are now offering some type of program to alleviate this type of problem. There is still the tremendously pressing problem of raising funds for the construction of waste treatment facilities. Even as the Federal Government bears a large part of the cost, there are still many financing problems.

Monitoring and Information

Present information systems and monitoring capabilities are not adequate. Monitoring systems are far from giving comprehensive coverage of all geographical areas. Information received from monitoring stations is often not readily or quickly available. There is a shortage of information on the amounts, types, and locations of pollutants discharged. Little has been done to combine data into a comprehensive picture. Thus, policymakers must base their decisions on much less than desirable amounts of information.

Special Problems in Agriculture

Agricultural pollution is extremely difficult to measure in many instances. This is due in part to the large number of acres involved in runoff and other pollution. It is much more difficult to measure pollution from such a large source than to measure point discharges. Point discharges are those coming from an identifiable single source. Preventing runoff from fertilizers is another fairly unique problem to agriculture, as is the prevention of runoff from animal wastes, particularly from feedlot operations. The broad spectrum of pesticides used has also become a problem. Return flow from irrigation with particularly high salt

concentrations is yet another problem. Considerable research and many innovations will be needed to help combat each of these problems. The Council on Environmental Quality, Federal agencies including the Environmental Protection Agency, and universities are presently evaluating the status of control techniques. Research and action approaches are also being looked into.

LOOKING TOWARD THE FUTURE

This nation is about to begin a major war on water pollution. This battle will not be of short duration nor easily won. Tighter enforcement programs and billion-dollar financing will lessen the worst water pollution problems. Other water pollution problems will then likely become apparent. There seems to be no simple solution to the problem of water pollution. Water-pollution control will require some drastic changes in industry, municipalities, and agriculture. The products that people consume may have to be changed. Large amounts of public and industrial funds will be required, and in some cases these high costs will be reflected in higher prices for products. Attaining high water quality standards is one of the great challenges facing our country. When finances and management combine to begin to turn the tide from worsening water pollution to better water quality standards, a significant achievement will have been reached.

SUMMARY

The following list of 18 recommendations from *Environmental Quality: The First Annual Report of the Council on Environmental Quality* covers the major areas that need to be taken care of to improve water quality.

1. Investment in waste treatment facilities must be significantly raised and kept at a sustained high level by enactment of the President's $4 billion program of federal grants.
2. Management reforms must be vigorously implemented to meet water quality goals effectively and efficiently.
3. The FWQA and other Federal waste treatment assistance programs should give priority to encouraging the development of regional treatment systems in metropolitan areas based on comprehensive sewer, water, and land use planning.
4. These Federal programs must also encourage localities to impose user charges on the amount and strength of wastes to increase equity and to work toward self-financing systems.
5. Vigorous and effective enforcement of water quality standards must be implemented.
6. Increased attention must be given to encouraging changes in State and local institutions dealing with water pollution control.
7. A concerted and comprehensive attack should be made on eutrophication.
8. A program should be formulated to deal with urban runoff and pollution from combined sewer overflows.
9. State programs need to be significantly improved.

10. Professional, technical, and operator manpower must be trained.
11. A strong and consistent Federal policy should be developed to control thermal pollution.
12. A policy and programs should be developed for ocean disposal of wastes.
13. More research, development, and demonstration are needed in several areas.
14. Efforts to ensure the safety of municipal water supplies should be increased.
15. More demonstrations on re-use and recycling of waste waters and sludge should be conducted.
16. Water quality management should be considered in the broader context of overall waste management.
17. The attack on problems from agricultural pollution should be intensified.
18. Mechanisms may be required to protect water against a wide variety of material that enters the environment and that is not covered under current regulatory authorities.

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